MI Proton Scraping and Tevatron Luminosity

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Beam-Beam

- saw before: pbars affect proton lifetime
  - introduced "PBJ" to control final pbar beam size
- ratio intensity/emittance, and relative beam sizes affect tune distributions of both beams, hence potentially lifetimes as well
- needed to have a procedure for generating desirable initial conditions
- want reproducible final results (L_0, lifetimes)

Luminosity

- Luminosity -- $$\mathcal{L} = \frac{f_0 B N \bar{N}}{2\pi(\sigma^{*2} + \bar{\sigma}^{*2})} \cdot \mathcal{H}$$
- Beam-beam has traditionally limited the ratio of N/ϵ -- for 2 IR's: $2 \cdot \xi = 3r_0 \cdot N/\epsilon \approx 0.025$, or so
- Re-write Luminosity -- $$\mathcal{L} = \frac{3 f_0 \gamma N (B\bar{N})}{\beta^*(\epsilon + \bar{\epsilon})} \cdot \mathcal{H}$$

(r_0 = classical radius of proton)

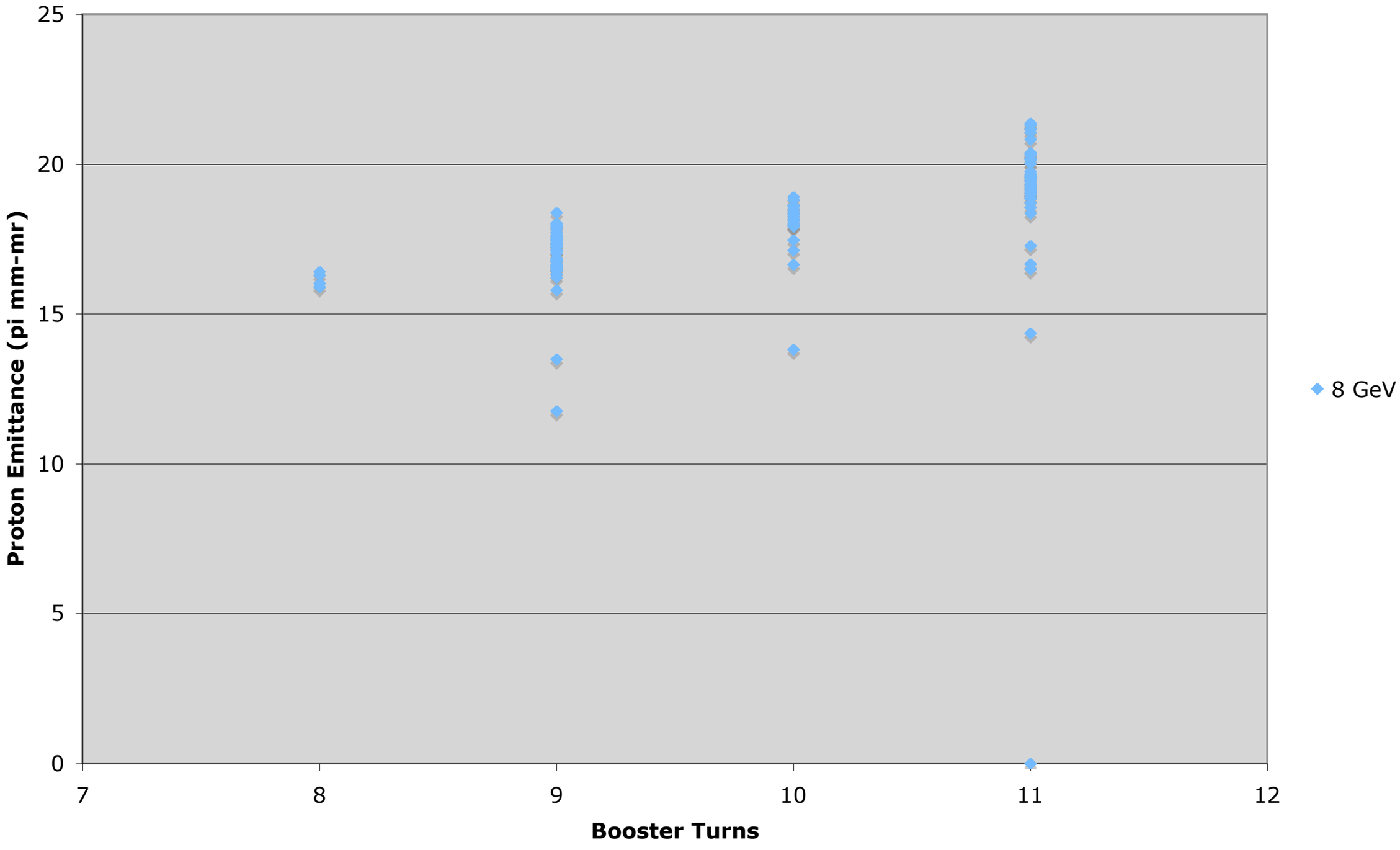
$$= \boxed{\frac{f_0 \gamma}{r_0 \beta^*} \cdot \frac{2\xi(B\bar{N})}{(1 + \bar{\epsilon}/\epsilon)} \cdot \mathcal{H}}$$

- So, keep $\bar{\epsilon}/\epsilon$ at an optimal value for b-b tune spread, push ξ to its limit; optimize initial pbar intensity for the given pbar accumulation rate

The upper curve

- 315 μb^{-1}/sec store (record)-- lots of pbars, but been there before; also had low p emittance
- observe wide swing in Booster emittance -- many best stores were w/ low Booster emittance
- when necessary to shoot from low stash size, how to optimize protons?
- all of above imply... "adjust" p emittance, to...
  - clean up tails, improve transfer efficiency, improve initial luminosity, and improve lifetimes

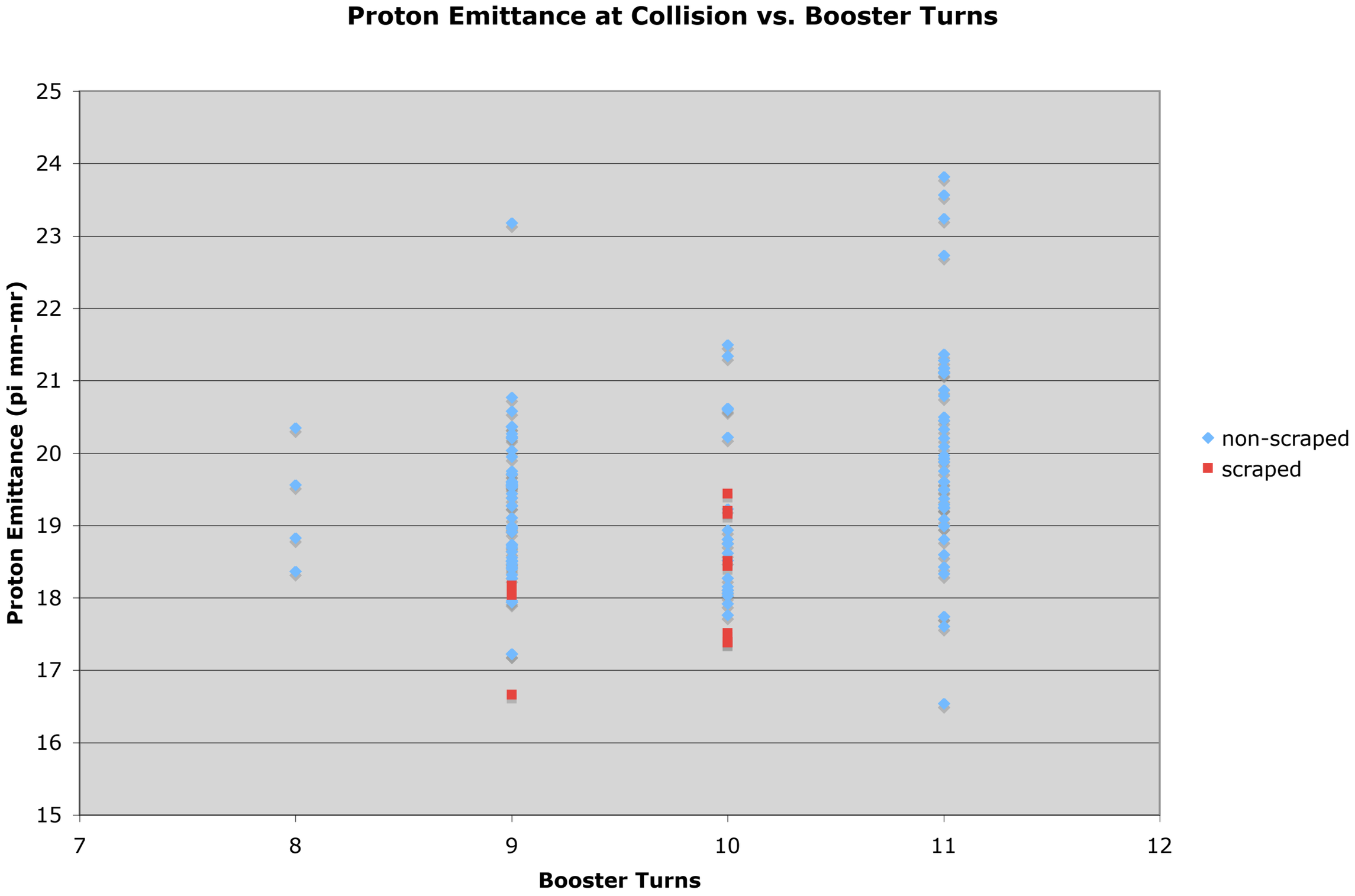
Booster Emittance



Beam Clean-up

- Combat changing initial conditions by cleaning up the beam in Main Injector at low energy
  - inject few more (5-10%) particles than necessary, then scrape to desired emittance/ intensity -- orbit bump at collimator in MI
    - try to make initial conditions reproducible
    - clean up tails, improve transfers/squeeze
- Naturally, still work on beam delivered from Booster; but procedure takes out the variations

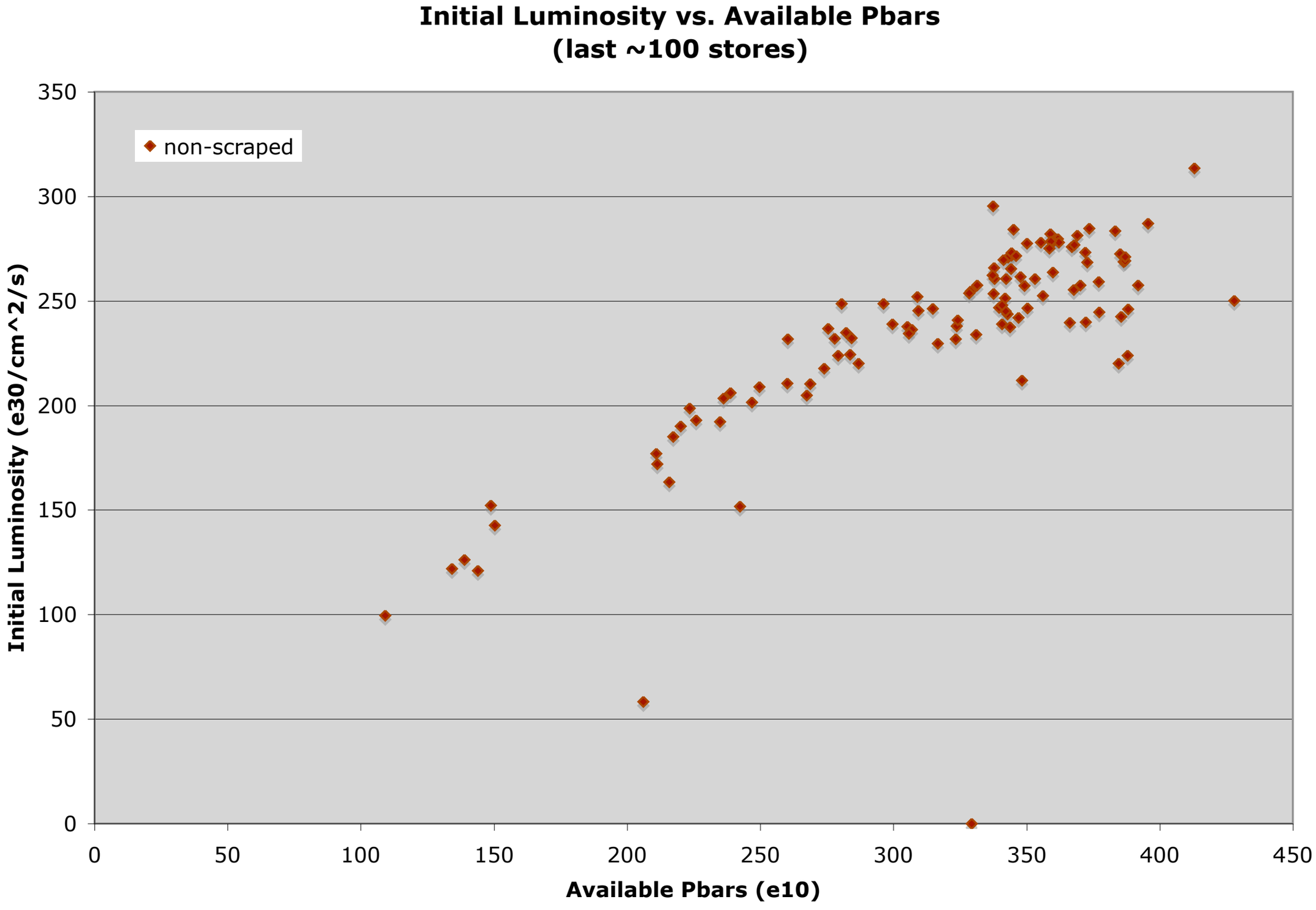
Results at 980 GeV



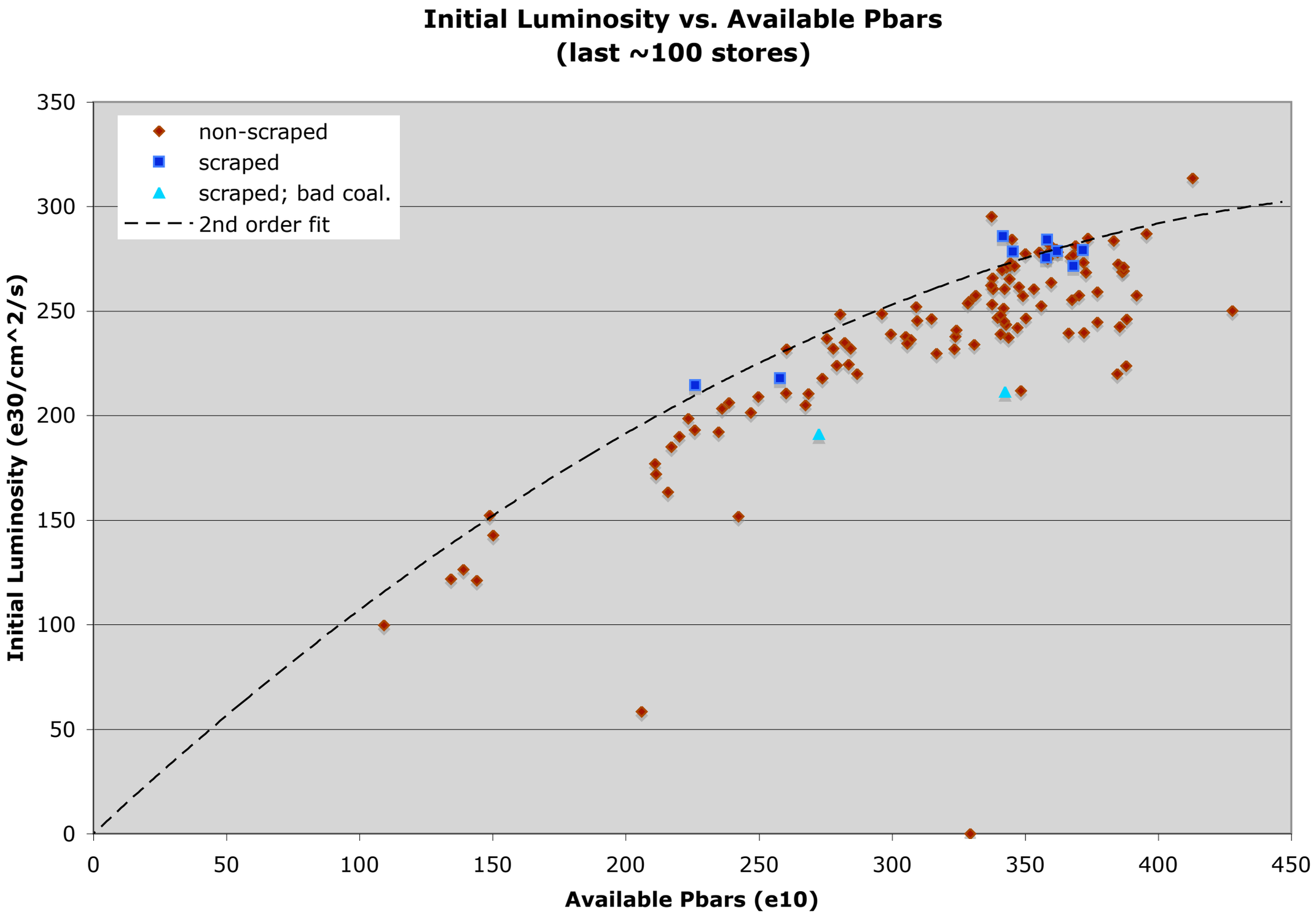
MI Beam Clean-up

- Use local orbit bump to move beam radially toward collimators in Main Injector to catch particles at edge of distribution
- compare w/ NuMI running...
  - ~1 shot/day: say remove 10% of ~10^{13} protons, + tune-ups -- results in total loss ≲2×10^{12} at 8 GeV
  - For comparison, a NuMI cycle loses roughly this much every ~2 sec; collimation system is built to handle

Historical Performance



Recent Performance



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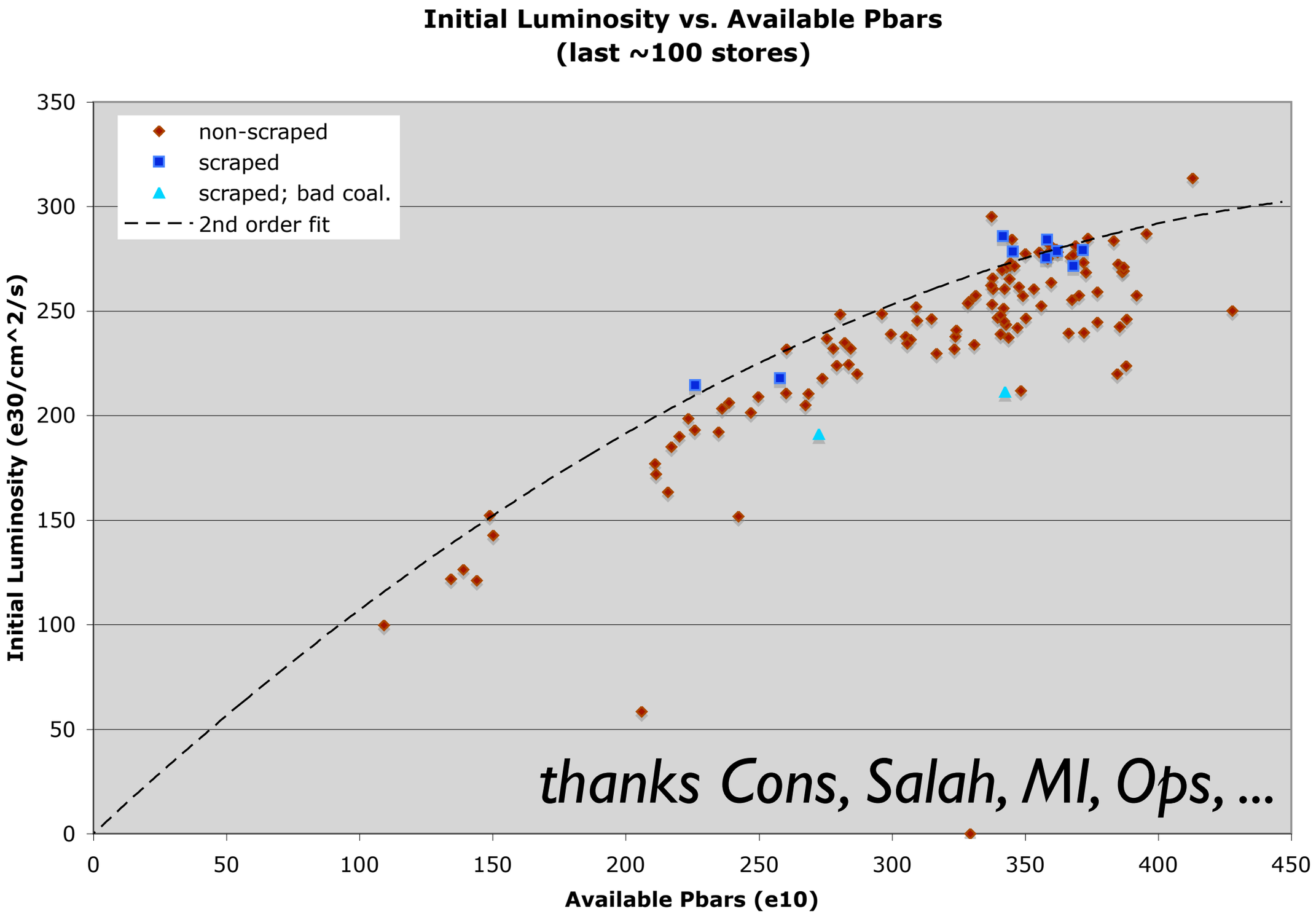


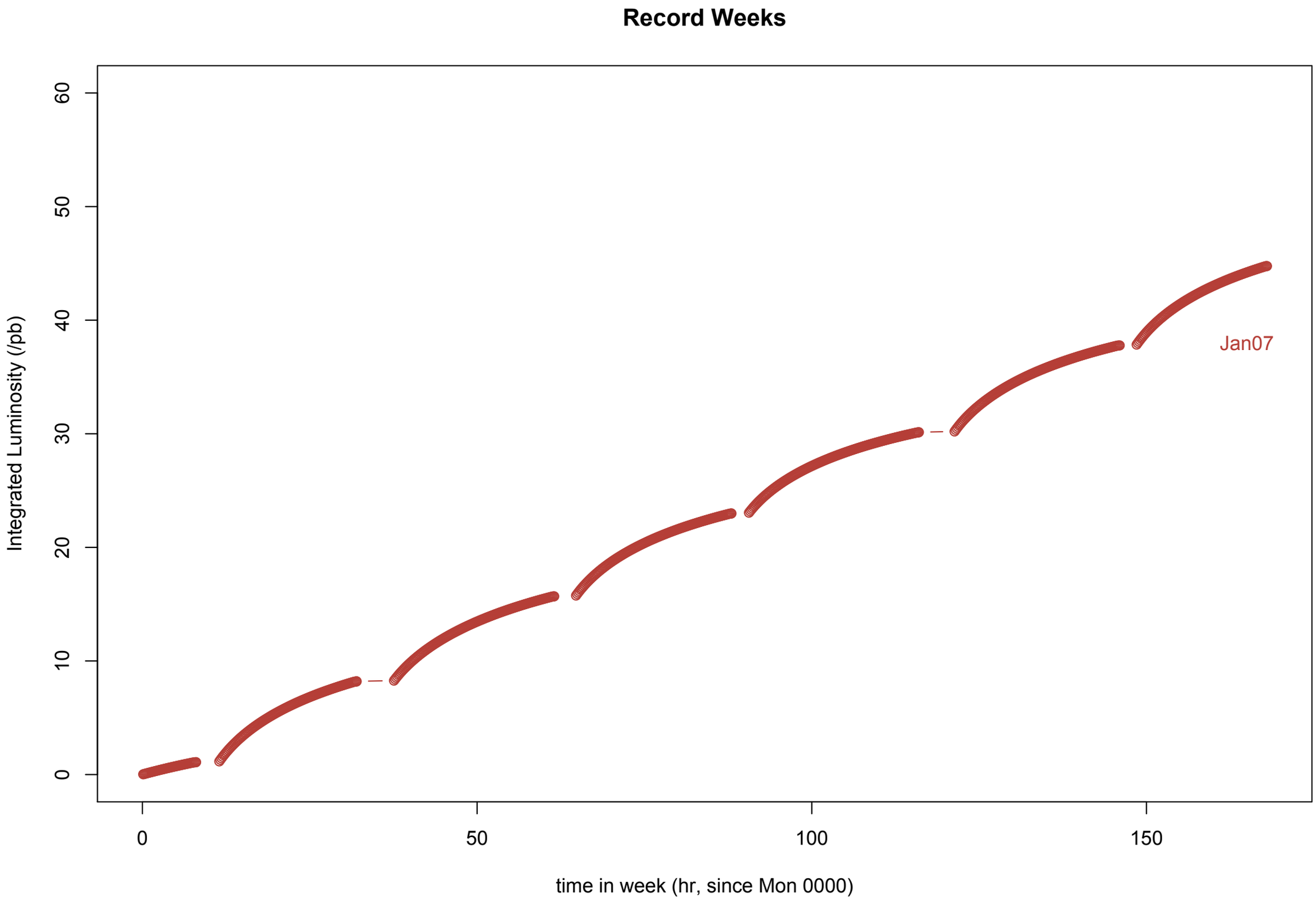
A Recipe

- First, make Reproducible Stores
- Inch up the *proton* N/eps toward its limit
  - use Booster Turns + MI scrape to generate
  - tailor *pbar* emittance (PBJ) to maintain good lifetimes
- Needs to be adiabatic process, to understand what's happening

Integrate...

- Experiments notice a (good) difference with scraped stores -- less losses, earlier start times
- When all systems work well, initial luminosities are very reproducible -- past two weeks, ~10 "good" stores from ~350x10^{10} Recycler stashes --
  - $\langle L_0 \rangle$ = 282 +/- 5 μb^{-1}/sec (*<2% spread!*)
- Continuing to stack well, faster turn-around times, and reproducible stores allow for shorter store times and higher integration per week

Record Weeks (Mon-Mon)



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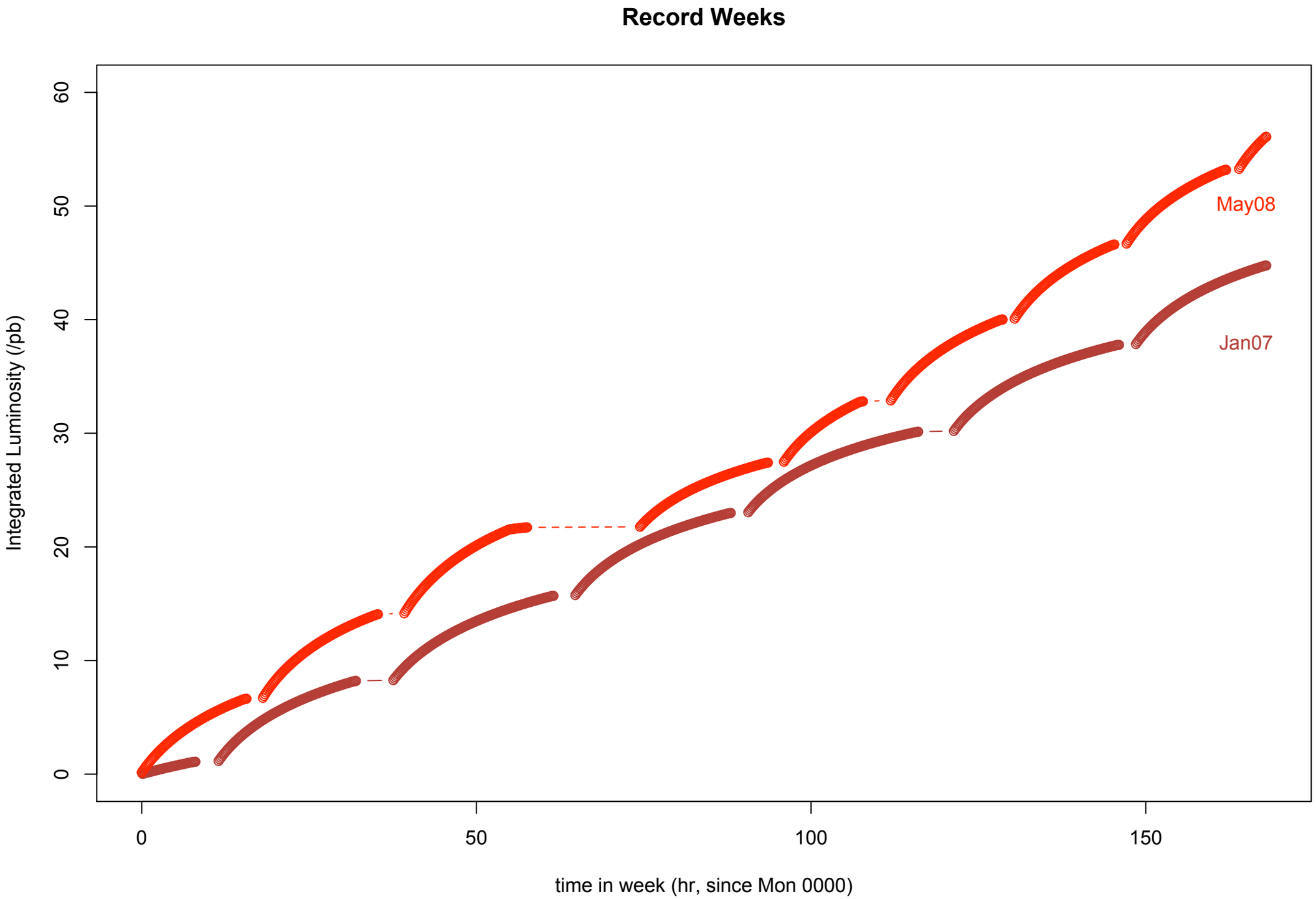

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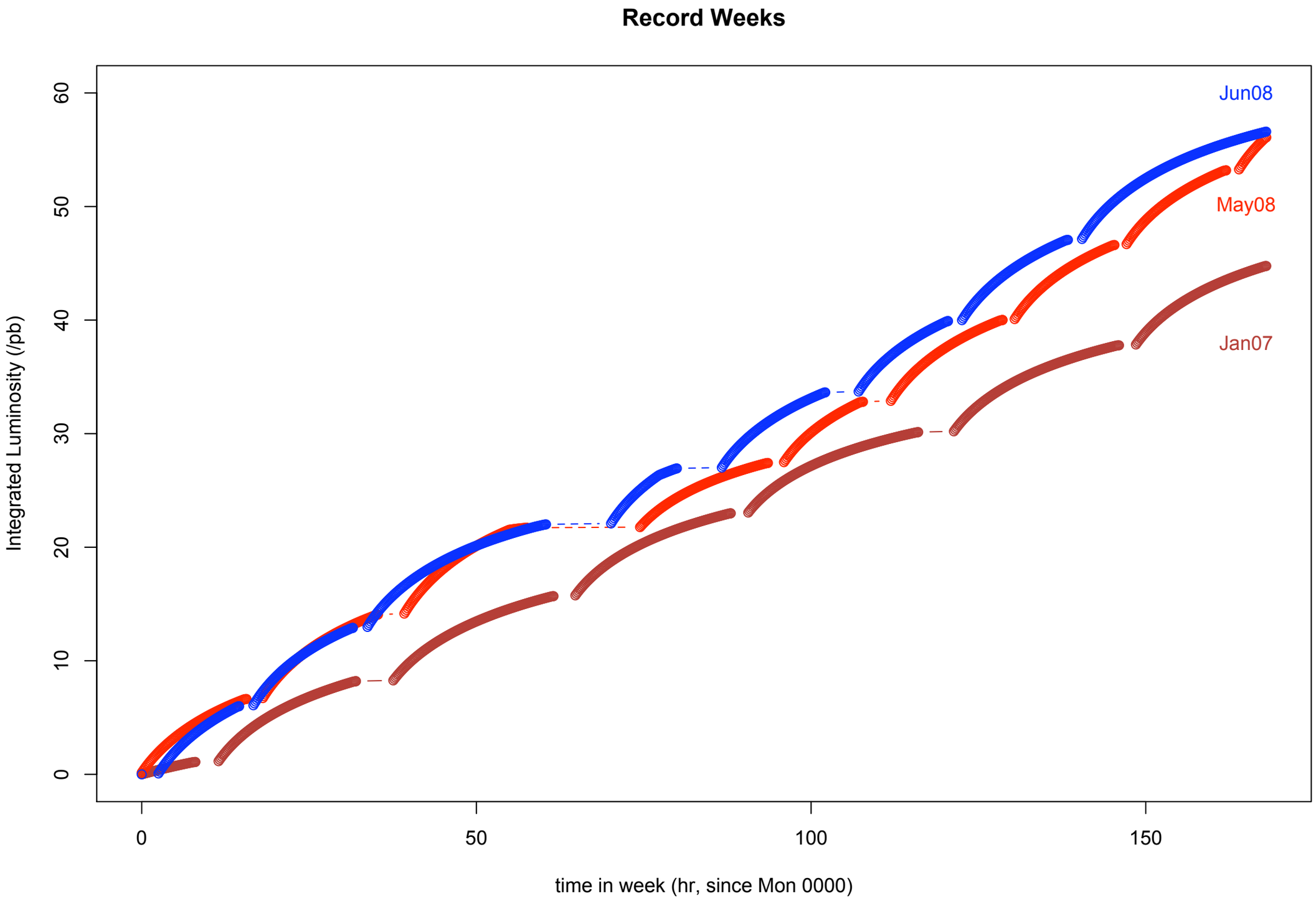

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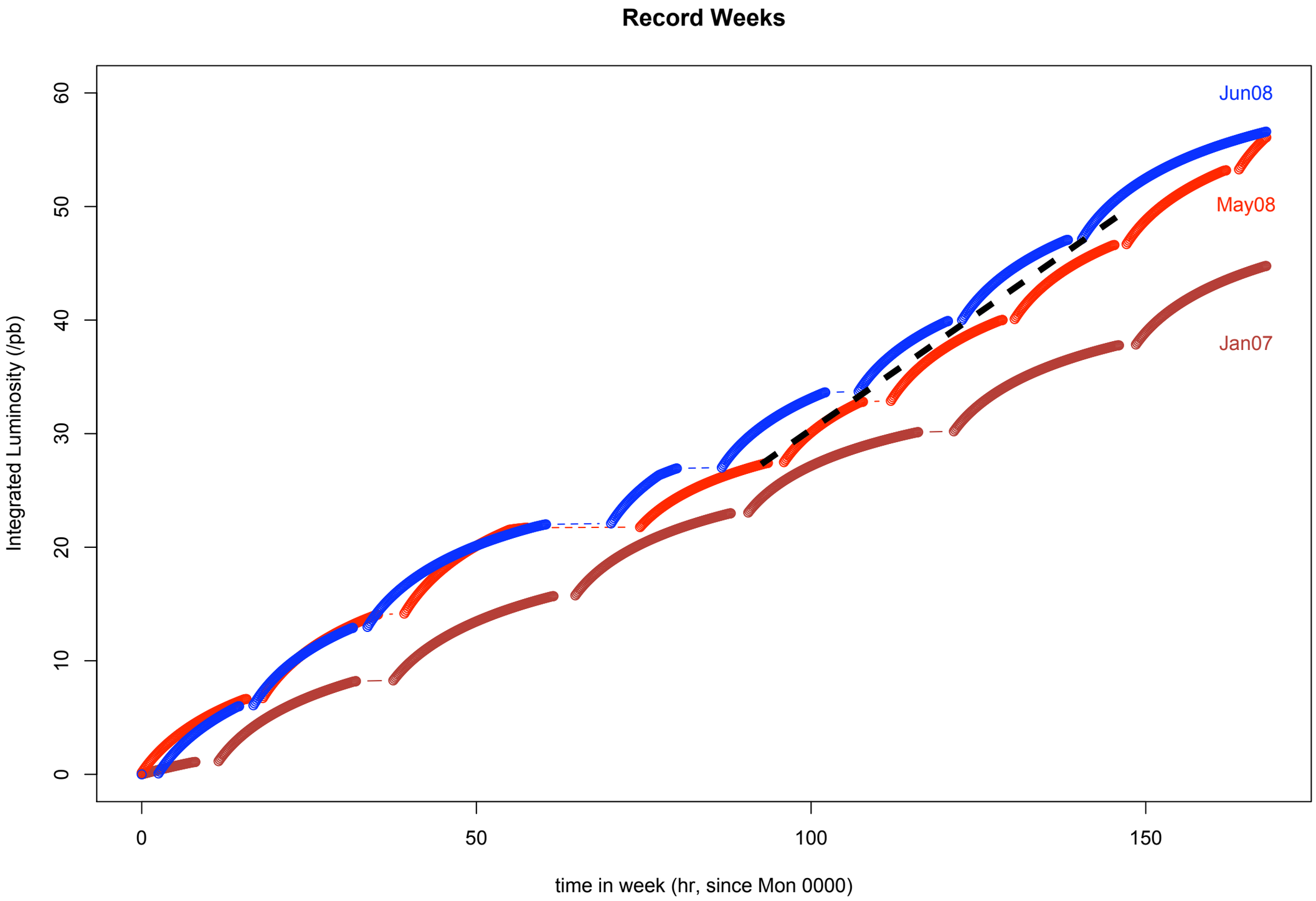

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